Practitioner's Docket No.: 782_163

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the application of: Toshihisa YOKOYAMA, Ken-ichi NODA, Katsuhiro IMAI and Minoru IMAEDA

Ser. No.: 09/854,924 Group Art Unit: 1765

Filed: May 14, 2001 Examiner: Song, M.

Confirmation No.: 7936

For: PROCESS AND APPARATUS FOR PRODUCING AN OXIDE SINGLE CRYSTAL

#14
4/16/03
mw

RULE 132 DECLARATION OF KATSUHIRO IMAI

I, Katsuhiro IMAI, hereby declare and state that:

1. I received a Doctor of Science degree in Mineralogy in March, 1993 from the University of Tokyo.

2. I have been employed by NGK Insulators, Ltd., the assignee of the above identified application, since April, 1993. During my employment with NGK, I have been involved with research and development of: single crystal materials at the Research Laboratory of NGK Insulators, Ltd., from April, 1993.

3. I have reviewed the prosecution history of the above-identified application, particularly the Final Office Action mailed January 15, 2003 and the Advisory Action mailed March 28, 2003. I have also reviewed Imaeda et al. and Ciszek et al., the applied prior art of record.

4. In the Advisory Action, the Examiner is taking the position that Applicants have not provided evidentiary support for the arguments that: 1) silicon crystals typically have a higher coefficient of thermal conductivity compared to that of oxide single crystals; and 2) silicon crystals typically have a lower coefficient of thermal expansion compared to that of oxide single crystals.

5. With reference to The Chemical Society of Japan (1993): *Kagaku Binran Kisohen* II (Handbook of Chemistry, Fundamental Chemistry Volume II), 4^{th} edition, Maruzen, Tokyo (in Japanese), a data sheet obtained from the INRAD, Inc., website http://www.inrad.com/pdf/Inrad_datasheet_LNB.pdf (a printout of which is attached hereto), oxide single crystals typically have a coefficient of thermal conductivity of 4W/m·K and coefficients of thermal expansion of 14.1×10^{-6}/K(//a) and 4.1×10^{-6}/K(//c), whereas silicon crystals typically have a coefficient of thermal conductivity of 148W/mK and a coefficient of thermal expansion of 4.15×10^{-6}/K. Therefore, those of ordinary skill in the art understand that silicon crystals have a higher coefficient of thermal conductivity and a lower coefficient of thermal expansion in comparison to oxide single crystals.

6. The Imaeda et al. reference relates to oxide single crystals and that reference correctly recognizes that it is undesirable to have too high of a cooling rate after growing the oxide single crystals. Although Imaeda et al. do not specifically address cooling oxide single crystals at the liquid-solid crystal interface, based on the disclosure in Imaeda et al., I would also conclude that one should not use a cooling gas to directly cool the oxide single crystal liquid-solid crystal interface. This is because the temperature at the liquid-solid crystal interface is necessarily higher than the temperature of the grown crystal body, and thus, blowing a cooling gas directly on the oxide single crystal solid-liquid crystal interface

would necessarily produce a greater rate of temperature change at the hotter liquid-solid crystal interface than would be realized if the same cooling medium were blown on the cooler crystal body. Therefore, for the same reasons that it is undesirable to have too high of a temperature gradient in the grown crystal body after crystal growth, as specifically disclosed by Imaeda et al., it is also undesirable to have too high of a temperature gradient at the liquid-solid crystal interface.

7. Ciszek deals with a method of producing a silicon crystal, which includes a step of directing a cooling medium onto the liquid-solid crystal interface portion. Ciszek's method is successful because of the relatively higher coefficient of thermal conductivity and the relatively lower coefficient of thermal expansion compared to those of oxide single crystals (see paragraph 5 above). On the other hand, blowing a cooling medium onto the liquid-solid crystal interface of Imaeda's oxide single crystal would not necessarily produce the benefits disclosed in Ciszek, because of the relatively lower coefficient of thermal conductivity and the relatively higher coefficient of thermal expansion of oxide single crystals. Therefore, skilled artisans would not conclude that oxide single crystals could withstand Ciszek's liquid-solid crystal interface cooling treatment, which, again, is designed for silicon crystals, because oxide single crystals have a lower coefficient of thermal conductivity and a higher coefficient of thermal expansion in comparison to silicon crystals.

8. Based on my academic credentials and work experience, I consider myself to be one of ordinary skill in the art. The claimed invention was not obvious to me at the time it was made. Nor do I believe that the claimed invention would have been obvious to others of ordinary skill in the art absent our discovery.

9. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

April 9, 2003
Date

Katsuhiro Imai
Katsuhiro Imai

Lithium Niobate ($LiNbO_3$)

PHYSICAL PROPERTIES

Chemical Formula	$LiNbO_3$ congruently melting[1]
Crystal Symmetry and Class	trigonal, R3c
Point Group	3m

Lattice Constants[2]
a = 5.15052(6) Å
c = 13.86496(3) Å

Density[2]	4.640(5) g/cm^3
Moh's Hardness	5

Fracture Toughness[3]	c-face	0.67 MPam$^{1/2}$
	x-face	1.07 MPam$^{1/2}$
	y-face	1.17 MPam$^{1/2}$

Elastic Compliance[4] at Constant Polarization (S_P) and at Constant Field (S_E) and Temperature Dependence[5]

(TPa)$^{-1}$	(TPa)-1	(10^{-4}/°K)
S_{P11}= 4.76	S_{E11}= 5.78	$(1/S_{E11})dS_{E11}/dT$=1.66
S_{P12}= -0.50	S_{E12}= - 1.01	$(1/S_{E12})dS_{E12}/dT$=0.28
S_{P13}= -1.20	S_{E13}= -1.47	$(1/S_{E13})dS_{E13}/dT$=1.94
S_{P14}= 1.02	S_{E14}= -1.02	$(1/S_{E14})dS_{E14}/dT$=1.33
S_{P33}= 4.10	S_{E33}= 5.02	$(1/S_{E22})dS_{E22}/dT$=1.60
S_{P44}= 9.3	S_{E44}= 17.0	$(1/S_{E44})dS_{E44}/dT$=2.05
S_{P66}= 10.5	S_{E66}= 13.6	$(1/S_{E66})dS_{E66}/dT$=1.43

Stiffness[4] at Constant Polarization (C_P) and at Constant Field (C_E) and Temperature Dependence[5]

(GPa)	(GPa)	(10^{-4}/°K)
C_{P11}= 219	C_{E11}= 203	$(1/C_{E11})dC_{E11}/dT$=-1.74
C_{P12}= 37	C_{E12}= 53	$(1/C_{E12})dC_{E12}/dT$=-2.52
C_{P13}= 76	C_{E13}= 75	$(1/C_{E13})dC_{E13}/dT$=-1.59
C_{P14}= -15	C_{E14}= 9	$(1/C_{E14})dC_{E14}/dT$=-2.14
C_{P22}= 252	C_{E22}= 245	$(1/C_{E22})dC_{E22}/dT$=-1.53
C_{P44}= 95	C_{E44}= 60	$(1/C_{E44})dC_{E44}/dT$= 2.04
C_{P66}= 91	C_{E66}= 75	$(1/C_{E66})dC_{E66}/dT$=-1.43

INRAD Lithium Niobate

OPTICAL AND ELECTRO-OPTICAL PROPERTIES

Optical Symmetry — uniaxial negative

Optical Transmission — 0.400 μm - 5.0 μm

Sellmeier Equation Constants[13]

$n = (A + B/(\lambda^2 + C) + D\lambda^2)^{1/2}$; λ in microns

n_o A=4.9048 B=0.11768 C= -0.0475 D= -0.027169

n_e A=4.582 B=0.099169 C=-0.044432 D= -0.02195

Calculated Refractive Index Values[12]

n_o(1.064 μm) = 2.2322 ; n_e(1.064 μm) = 2.1560

n_o(2.060 μm) = 2.1949 ; n_e(2.060 μm) = 2.1243

n_o(3.500 μm) = 2.1405 ; n_e(3.500 μm) = 2.0788

Photoelastic Strain Coefficients at Constant Field[11]

p_{11} = -0.026	p_{31} = 0.17
p_{12} = 0.08	p_{33} = 0.07
p_{13} = 0.13	p_{41} = -0.151
p_{14} = -0.08	p_{44} = 0.146

Temperature Variation of Refractive Index[13] for λ = 1.0 μm – 4.0 μm

$dn_o/dT = 3.3 \times 10^{-6}$ /°C

$dn_e/dT = 37 \times 10^{-6}$ /°C

Nonlinear d Coefficients[12,20]

d_{22} = 2.4 pm/V

d_{31} = -4.52 pm/V

d_{33} = 31.5 pm/V

Effective Nonlinear Optical Coefficient

$d_{eff} = d_{31} \sin\theta - d_{22} \cos\theta \sin 3\Phi$

Electro Optic Coefficients @ 0.633 μm[23]

r_{13}^T = 10 pm/V	r_{13}^S = 8.6 pm/V
r_{22}^T = 6.8 pm/V	r_{22}^S = 3.4 pm/V
r_{33}^T = 32.2 pm/V	r_{33}^S = 30.8 pm/V
r_{51}^T = 32 pm/V	r_{51}^S = 28 pm/V

Variation of Electro Optic Coefficient r_{22} with Wavelength[22]
And Calculated Half-wave Voltage For 9mmx9mmx25mm Q-Switch

$V_{1/4} = \lambda d / (4 n^3 l r_{22})$

r_{22}^T	$V_{1/4}$
1.064 μm = 5.6 pm/V	1.55 kVolts
1.318 μm = 5.4 pm/V	2.02 kVolts
1.55 μm = 5.3 pm/V	2.44 kVolts
2.10 μm = 5.2 pm/V	3.45 kVolts
2.79 μm = 5.1 pm/V	4.78 kVolts
2.94 μm = 5.1 pm/V	5.08 kVolts

Damage Threshold[2] — 3 J/cm² @ 10 nsec

THERMAL AND ELECTRICAL PROPERTIES

Melting Point[7]	1240° C
Curie Temperature[8]	1145° C
Thermal Conductivity[9]	4. W/m°K
Thermal diffusivity[6]	9×10^{-7} m²/sec
Specific Heat[9]	0.633 J/g°K
Thermal Expansion[10]	$\alpha_a = 14.1 \times 10^{-6}$/°K $\alpha_c = 4.1 \times 10^{-6}$/°K
Resistivity[14]	2×10^{10} Ω - cm @ 200° C

Dielectric Constants[15]

$K_{11}^S = 43$ $K_{11}^T = 78$

$K_{33}^S = 28$ $K_{33}^T = 32$

Loss tangent[15] @400 °C

x-axis Tanδ =0.0006

y-axis Tanδ =0.001

Typical Polish Specifications

Wavefront Distortion:	λ / 8 @ 633 nm
Flatness:	λ / 10 @ 633 nm
Parallelism:	1 arcseconds
Scratch - Dig:	10 - 5

INRAD Lithium Niobate

Description

Lithium niobate is a ferroelectric material suitable for a variety of applications. Its versatility is made possible by the excellent electro-optic, nonlinear, and piezoelectric properties of the intrinsic material. It is one of the most thoroughly characterized electro-optic materials, and crystal growing techniques consistently produce large crystals of high perfection.

Applications that utilize the large electro-optic coefficients of lithium niobate are optical modulation and Q-switching of infrared wavelengths. Because the crystal is nonhygroscopic and has a low half-wave voltage, it is often the material of choice for Q-switches in military applications. The crystal can be operated in a Q-switch configuration with zero residual birefringence and with an electric field that is transverse to the direction of light propagation. Because piezoelectric ringing can be severe, piezoelectrically damped designs can be very useful. The damage threshold of the intrinsic material at 1.06 microns with a 10 nsec pulse is approximately 3 J/cm^2. With appropriate AR coatings, a surface damage threshold of 300-500 MW/cm^2 can be achieved for the same conditions.

Applications that use the large nonlinear d coefficient of $LiNbO_3$ include optical parametric oscillaton, difference frequency mixing to generate tunable infrared wavelengths, and second harmonic generation. With a broad spectral transmission, which ranges from 0.4 µm to 5.0 µm with an OH^- absorption at 2.87 µm, a large negative birefringence, and a large nonlinear coefficient, phasematching is an effective way to generate tunable wavelengths over a broad wavelength range.

Lithium niobate is particularly effective for second harmonic generation of low power laser diodes in the 1.3 to 1.55 µm range.

For infrared generation by difference frequency mixing, the peak power limit is considerably lower than for 1.064 µm, being about 40 MW/cm^2. Efficiencies for difference frequency mixing generally are smaller than shg efficiencies with KDP or BBO, which is due to the lower peak powers that can be tolerated by the crystal and the fact that the longer wavelength photons that are generated in the process are less energetic. Typical powers for 10 nanosecond long pulses with 5 mm diameter beams are 30 mJ/pulse of 0.640 µm minus 40 mJ/pulse of 1.064 µm to produce 2.5 mJ/pulse at 1.54 µm, and 32 mJ/pulse of 0.532 µm minus 32 mJ/pulse of 0.640 µm to produce 0.25 mJ/pulse at 3.42 µm.

INRAD offers lithium niobate in a variety of configurations. Standard cuts are available as OPO crystals, Q-switches, difference frequency mixing crystals, autocorrelation crystals, and optical waveguide wafers.

Please consult an INRAD sales engineer for assistance in crystal selection and packaging.

At INRAD, all crystal growth, orientation, fabrication, polishing, and testing of $LiNbO_3$ is done at one site so that you are assured of complete traceability and satisfaction with every crystal that you purchase.

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5・2 膨張率と圧縮率

5・2・1 固体単体の線膨張率および体膨張率

セルシウス温度が0℃およびθにおける長さおよび体積を、それぞれ l_0, v_0 および l, v とすれば、一般に線膨張率 β および体膨張率 α はそれぞれ

$$\beta=\frac{1}{l_0}\frac{dl}{d\theta} \qquad (5\cdot1)$$

$$\alpha=\frac{1}{v_0}\frac{dv}{d\theta} \qquad (5\cdot2)$$

で与えられる。

二つの温度 θ_1 および θ_2 における値をそれぞれ l_1, v_1 および l_2, v_2 とすれば、θ_1 と θ_2 との間の平均線膨張率 β_m および平均体膨張率 α_m はそれぞれ

$$\beta_m=\frac{1}{l_0}\frac{l_2-l_1}{\theta_2-\theta_1} \qquad (5\cdot3)$$

$$\alpha_m=\frac{1}{v_0}\frac{v_2-v_1}{\theta_2-\theta_1} \qquad (5\cdot4)$$

で与えられる。さらに精密な目的に対しては

$$l=l_0(1+\beta_1\theta+\beta_2\theta^2+\beta_3\theta^3) \qquad (5\cdot5)$$

$$v=v_0(1+\alpha_1\theta+\alpha_2\theta^2+\alpha_3\theta^3) \qquad (5\cdot6)$$

で表わされる。なお等方性の物質では $\alpha=3\beta$ である。

表 5・29 固体単体の線膨張率 β[1)]

物質		θ/℃	β または β_m / $10^{-4}K^{-1}$	物質		θ/℃	β または β_m / $10^{-4}K^{-1}$	物質		θ/℃	β または β_m / $10^{-4}K^{-1}$
Ag		−190～0	0.170	Fe		0～898	0.1376	Pd		0～100	0.106
		0～100	0.193		γ体	916～922	0.120	Pt		0～100	0.0899
Al		−190～0	0.189	Ga		−73.3～18	0.53			0～900	0.0994
		0～100	0.237	Ge		0～400	0.077	Rb		20	0.963
		20～300	0.258	Hg	∥c軸	−188～−79	0.470	Re		12～50	0.065
As	∥c軸	6	0.48		⊥c軸	〃	0.375	Rh		0～50	0.096
	⊥c軸	6	0.05	I		−80～28	2.20*1	Ru		19～32	0.0975
Au		−190～0	0.131	In		0～100	0.56	S		−223～−185	0.711*1
		0～100	0.142	Ir		0～100	0.0658			−196～−79	1.50*1
Be		20	0.15	K		0～50	0.83			−79～18	3.80*1
Bi	∥c軸	20～240	0.102	La		0～300	0.065			(mp)*2	3560*1
	⊥c軸	20～240	0.120	Li		0～96	0.56	Sb	∥c軸	20～100	0.1917
Br_2		−273～−194	2.00*1	Mg	∥c軸	16～35	0.271		⊥c軸	〃	0.080
C	ダイヤモンド	0～70	0.0128		⊥c軸	〃	0.243	Si		10～50	0.0415
	黒鉛 ∥c軸	20～40	0.05965	Mn	α体	−20～0	0.2153	Sn	∥c軸	0～20	0.3800
	a軸	1000～1600	0.0095	Mo		0～100	0.051		⊥c軸	0～20	0.1583
	c軸	1000～1600	0.2805	Na		0	0.686	Ta	焼鈍	20～100	0.065
Cd	∥c軸	20～100	0.526			0～100	0.71		焼なまし	〃	0.067
	⊥c軸	〃	0.214			−97.6	2.78*1	Te	∥c軸	～20	−0.016
Co		20～100	0.126	Ni		0～100	0.125		⊥c軸	〃	0.272
		100～200	0.136			500～600	0.165	Tl		0～100	0.294
Cr		0～100	0.084			600～900	0.178			100～200	0.300
Cs		～20	0.97	Os		0～100	0.070	W		0～100	0.045
Cu		−185～−103	0.121	P		−79～19	3.75*1	Zn	∥c軸	20～250	0.530
		−103～0	0.154			24～60	5.60*1		⊥c軸	〃	0.150
		0～101	0.162	Pb		0～100	0.290	Zr		−20～0	0.0563
		300	0.175			20～300	0.313			0～100	0.543*1

1) "Landolt-Börnstein Zahlenwerte und Funktionen aus Physik, Chemie, Astronomie, Geophysik und Technik", 6 Aufl., II Band, 1 Teil, S. 379～448, Springer-Verlag (1971).

*1 体膨張率 α または α_m を表わす。

*2 融点

5・2・2 化合物の線膨張率および体膨張率[1)]

表 5・30 固体化合物の体膨張率 α および線膨張率 β (I)

化合物	θ/℃	α または α_m / $10^{-4}K^{-1}$	化合物	θ/℃	α または α_m / $10^{-4}K^{-1}$	化合物	θ/℃	α または α_m / $10^{-4}K^{-1}$
等軸晶系化合物			H_2O(氷)	−73	0.376*	KI	−79～0	1.25
AgCl	20～150	1.03		0	0.558*	$KMnO_4$	−78～18	2.20
Al_2O_3	20～800	0.000	$H_2SO_4\cdot H_2O$	−78～0	2.20	KNO_3	−78～18	2.10
$BaCl_2$	20～150	0.60	KBr	−79～0	1.10	KOH	30～120	1.06
$CaCl_2$	20～150	0.67	KCl	−78～25	1.01	K_2SO_4	−78～21	1.30
CaO	30～75	0.21*	$KClO_3$	−78～21	2.20	MgO	30～75	0.133*

* 線膨張率 β または β_m を表わす。

1) "Landolt-Börnstein Zahlenwerte und Funktionen aus Physik, Chemie, Astronomie, Geophysik und Technik", 6 Aufl., II Band, 1 Teil, S. 449～778, Springer-Verlag (1971).

表 8・63 固体単体の熱伝導率*1,*2 $k/\mathrm{W\,m^{-1}\,K^{-1}}$

固体	温度 T/K							固体	温度 T/K						
	50	100	200	300	400	700	1000		50	100	200	300	400	700	1000
Ag	700	430	430	427	420	397	374	Mo	300	179	143	138	134	123	112
Au	420	355	327	315	312	293	278	Na	106	133	138	132	(85.5)	(71.5)	(58.9)
B	404	190	52.6	27.6	13.7	6.41	5.29	Nb	76	55.2	52.6	53.7	55.2	59.8	64.4
Be	4000	990	301	200	161	115	89.7	Nd			16.6	16.5	16.8	10.9	21.5
Bi(⊥c)	30.7	18.8	11.3	8.15	8.22	(24.1)	(16.8)	Ni	336	158	106	90.5	80.1	65.5	71.8
[illegible]	2500	3010	1430	900	632			Os	285	112	90.8	87.6	86.9		86.5
[illegible]	9200	10000	4040	2310	1550			P(黒)	42.7	30.7	17.7	12.1			
[illegible]	3900	3450	2260	1350	936			Pb	43.5	39.6	36.6	35.3	33.8	(17.4)	(21.5)
(黒鉛⊥)	17	58	120	129	118	85	64	Pd	123	77.3	75.5	75.5	76.5	75.5	79.5
(黒鉛∥)	19	42	86	98	90	65	[illegible]	Pr		7.09	10.6	12.5	13.6	16.3	21.6
(Pyr.∥c)	2300	4980	3250	2600	1480	790	520	Rb	62.7	60.3	58.9	58.2	(33.1)	(28.9)	(25.7)
(Pyr.⊥c)	103	39	15	9.5	7.0	5.8	2.5	Re	96.2	58.9	51.0	47.9	46.1	44.0	44.6
[illegible]	120	103	99.3	98.8	94.7	(49.0)		Rh	570	186	154	150	146	131	121
[illegible]	3.79	6.00	6.00	11.4	13.3	10.0	21.6	Ru	695	154	118	117	115		
[illegible]	298	168	122	99.3	84.8			S	0.977	0.522	0.355	0.269	(0.152)		
[illegible]	317	156	111	80.3	87.3	73.7	65.3	Sb	88.3	48.4	30.2	24.3	21.2	17.4	(27.0)
[illegible]	44.7	20.7	35.8	35.9	(20.3)	(20.1)	(17.5)	Sc	13.5	14.9	15.3	15.8			
[illegible]	13.5	10.5	9.59	10.7	10.9	13.9	15.2	Se(∥c)	80.3	10.3	6.08	4.52	5.36		
[illegible]	8.28	11.9	14.3	14.3	13.9	14.8	15.8	Si	2680	884	264	148	98.9	50.0	31.2
[illegible]	372	132	94	80.3	69.4	48.7	32.5	Sm	7.52	7.35	11.3	[illegible]	13.3		
[illegible]	63.4	47.4	42.4	40.5	(37.0)			Sn	115	85	73.3	66.6	62.2	(31.3)	(40.5)
[illegible]	19.0	11.5	9.98	9.38	10.1			Ta	72	59.2	57.5	57.5	57.8	59	60.2
[illegible]	815	232	96.8	59.9	43.2	22.7	17.4	Tb	14.7	11	9.98	11.1			
[illegible]	25.1	26.0	24.4	23.0	22.3	21.0	20.7	Te(∥c)	45.4	25.9	5.10	3.35	2.94	2.20	
[illegible]	35.4	32.0	28.0	(8.34)	(9.84)	(12.7)	(11.7)	Th	63.2	48.8	40.6	45.1	50.3	50.4	51.5
[illegible]	7.77	7.62	15.0	13.0	13.4			Ti	40.1	31.2	24.5	21.9	20.4	19.4	20.7
[illegible]				0.449	(0.114)	(0.058)		Tl	62.5	56.6	48.4	46.1	43.8		
[illegible]	104	97.6	89.7	81.7	74.6	41.4	52.4	Tm	19.3	23.5	16.2	16.8			
[illegible]	472	172	153	147	146	135	126	U	16.9	21.7	25.1	27.6	29.6	35.6	43.9
[illegible]	112	107	104	102	(32.0)	(40.6)	(31.3)	V	40.5	35.7	31.5	31.5	32.1	35.8	38.6
[illegible]	0.43	9.78	11.8	13.6	14.0	13.6	20.9	Y	16.5	13.7	15.5	16.2	16.9	20.3	23.5
[illegible]	235	114	88.1	76.8	72.1	(50.9)	(60.0)	Yb			38.1	34.5	36.1		
[illegible]	20.9	18.9	17.2	16.2				Zn	273	124	123	121	116	(49.6)	(60.7)
[illegible]	375	169	159	156	153	147	(81)	Zr	48.7	33.2	25.2	22.7	21.6	20.8	23.7
[illegible]	4.05	5.70	7.17	7.82											

*1 表中の( )を付けた数値は液相の値である。

*2 元素名に付けた⊥，∥c などは，単結晶試料の c 軸に垂直，c 軸に平行などを示す。ただし，C(黒鉛)については，ATJ 黒鉛の加圧成形時の圧縮方向に対する垂直(⊥)，平行(∥)を示し，C(Pyr.)は熱分解黒鉛を示す。

表 8・64 ガラスと酸化物の熱伝導率 $k/\mathrm{W\,m^{-1}\,K^{-1}}$

固体	温度 T/K						
	100	200	300	400	500	700	1000
石英ガラス (SiO_2)	0.69	1.14	1.38	1.51	1.62	1.92	2.87
ガラス (Pyrex 7740)*1	0.58	0.90	1.10	1.25	1.36	1.65	
パイロセラム (9606)*2	5.42	4.74	3.99	3.65	3.45	3.19	2.97
Al_2O_3 (サファイア)	450	82	46	32.4	24.2	13.4	10.5
(多結晶)	133	55	36	26.4	20.2	12.6	7.9
[illegible]		424	378	196	146	87	47

固体	温度 T/K						
	100	200	300	400	500	700	1000
MgO	270	94	60	48.1	32		
SiO_2							
(石英∥c 軸)	39	16.4	10.4	7.6	6.0	4.5	
(石英⊥c 軸)	20.8	9.5	6.2	4.7	3.9	3.1	
ThO_2			13.2	10.2	8.1	5.5	3.7
TiO_2							
(ルチル∥c 軸)	23.5	13.7	10.4	8.5			
(ルチル⊥c 軸)	16.9	9.7	7.4	6.0			
(多結晶)			8.4	7.0	5.8	4.4	3.5
UO_2	6.0	8.6	8.2	7.4	6.5	5.1	3.8

*1 Corning 社製，$\rho=2.2263\ \mathrm{g\,cm^{-3}}$

*2 Corning 社製，$\rho=2.601\ \mathrm{g\,cm^{-3}}$